

**Training Systems Research for 21st Century Warfighters:
Identifying Mission Essential Competencies for Simulation-based Training and Rehearsal**

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ABSTRACT

The Air Force Research Laboratory, Human Effectiveness Directorate has developed a comprehensive approach to mission planning, rehearsal, and training called Distributed Mission Training (DMT). We have developed a high fidelity simulation testbed to explore the impact of principled training on individual and team performance. The information obtained in our testbed is crucial to assessing the impact of the Air Force's ground and flying training and rehearsal methods. The information is also of singular importance in identifying disconnects and shortfalls between our methods and the operational requirements of combat pilots and teams. This presentation will highlight challenges in the development and use of high fidelity simulation environments for enhancing individual and team performance. We will focus on issues related to defining mission essential competencies for aerospace operations and on the use of these competencies for specifying learning objectives and for developing training scenarios. We will also highlight recent work to develop valid criteria for evaluating the performance of pilots as individuals and as part of a four-ship team in the environment and the relationship of this performance to actual flying operations.

INTRODUCTION

The Air Force's Distributed Mission Training (DMT) program is a major advance in ground-based training that will allow pilots and other warfighters to train for complex, multi-player combat operations using a network of flight simulators and other systems. Chapman (1998) states that,

The DMT network will be created incrementally, focusing first on team training. F-15C and AWACS *Missions Training Centers* (MTCs) will be the first DMT constituents. MTCs will house the unit's simulators or mission training system, briefing and debriefing systems, threat stations and simulations, and the infrastructure needed for local and wide area networking. (p. 1)

Researchers from the Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA) are investigating strategies for incorporating DMT into advanced flying training in operational units. When reviewing the utility of an earlier generation of training systems, Polzella, Hubbard, Brown, and McLean (1987) discovered that many of the instructional features that had been incorporated into Air Force flight training simulators were

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14. ABSTRACT The 42nd Annual Conference of the International Military Testing Association met in Edinburgh, Scotland, on 7-9 Nov 2000. Representatives of various armed services of the US and other nations. This conference fosters improved personnel assessment for behavioral measurement, occupational analysis, manpower analysis, simulation models, training programs, selection methodology, survey and feedback systems. It promotes cooperation in the exchange of assessment procedures and instruments, and promotes assessment of military personnel as a scientific adjunct to modern military personnel management. Attached are three papers prepared by personnel of the Air Force Research Laboratory's Warfighter Readiness Research Division, relevant to the objectives of this conference which are included in the conference proceedings. Paper 1: Training Systems Research for 21st Century Warfighters: Identifying Mission Essential Competencies for Simulation-based Training and Rehearsal, by Bennett, W., Jr., Crane, P., & Tucker, R. ; Paper 2: Development of Models of Alternative Space Training Structures, by Bennett, W., Sorenson, B., & Stone, B.; and Paper 3: Adaptive, Internet Survey Techniques for Determining Critical Pilot Training Tasks and Requirements, by Sidor, G., Bergondy, M., Arthur, W., Jr., Mitchell, J., & Bennett, W.					
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unwanted and unused. A primary goal of DMT research at AFRL/HEA is to provide commanders and instructors at MTCs with effective and validated training tools and materials including training protocols to meet specific needs, sample scenarios, and performance assessment instruments. The laboratory's objective is to assist Air Force warfighters use DMT systems to effectively and efficiently augment flying training.

Background

Research on training effectiveness of multi-ship simulation systems has been on-going at AFRL/HEA for almost ten years. In addition to research on networked simulation technologies, activities have focused on application of DMT for continuation training of fighter pilots and air weapons controllers. Hoog (1999) described how DMT systems are being designed to enhance skills that warfighters will employ both as individuals and as members of a team. Effective application of multi-player simulation for enhancing individual and team skills has been demonstrated for F-15 pilots (Houck, Thomas, & Bell, 1991), F-16 pilots (Berger & Crane, 1993), Tornado pilots and navigators (Huddleston, Harris, & Tinsworth, 1999), pilots, forward air controllers, and ground forces executing close air support (Bell, et al., 1996), and Air Force Special Operations teams (Nullmeyer & Spiker, in press). F-16 pilots who have flown in a distributed environment have rated DMT as particularly effective for training four-ship air-to-air employment against multiple enemy aircraft (Crane, Schiflett, & Oser, 2000). F-16 pilots have identified individual skills including radar mechanization (i. e., using the various modes and capabilities of the air-to-air radar to detect, track, and target multiple aircraft), communication, and building situation awareness as being enhanced by DMT. Team skills enhanced by DMT include maintaining mutual support, tactical execution, and flight leadership.

One of the most critical aspects of developing high performance flying missions is related to the identification of mission essential competencies that can be used to define combat readiness. The Air Force has attempted to specify readiness and mission performance requirements at a number of levels of abstraction. These levels of abstraction include very specific task level behaviors that must be performed to operate fighter aircraft. They also include very broad statements of the Air Force Mission Essential Tasks, which are global statements of the overall missions and goals of the Air Force and its component organizations. In most cases these more specific task level behaviors are the focus of Undergraduate Pilot Training and Initial Qualifications Training (IQT).

From the time an Air Force pilot completed IQT until they are certified as "Combat Mission Ready" they are basically required to completed a variety of formal and information training and operational requirements as a part of the Ready Aircrew Program (RAP). However, the specificity of

Crane (1999) reported that F-16 instructor pilots participating in DMT research would frequently fly as flight leader for the morning mission but would then assign a less experienced pilot to serve as flight lead during the afternoon. The instructors explained that these pilots were participating in Flight Lead Upgrade (FLUG) training at their squadrons and that DMT was a valuable complement to aircraft training. As applied to FLUG training, results to date demonstrate that experience in DMT enhances leadership skills for multi-ship, multi-bandit air combat. This is most likely a function of both DMT system capabilities and constraints on

pilots' ability to train in the aircraft that limit opportunities for gaining experience over a wide range of tactical situations. Observations of pilots during DMT-FLUG exercises demonstrated that increases in mission performance resulted from both enhanced skills and from opportunities to review missions and to assess the results of individual actions.

One of the objectives of DMT-FLUG research was to identify the ways in which DMT experience could increase pilot readiness for FLUG missions. These examples illustrate two training benefits of DMT. The first is providing increased opportunities to train individual skills that must take place in a multi-player context. Radar sorting and targeting requires multiple friendly and enemy aircraft; opportunities to practice this skill in the air are highly limited. DMT provides many opportunities to practice this skill in a naturalistic context and within a short period of time. This observation is in agreement with Bell (1999) and Schneider (1989) who propose that multiple opportunities to practice a skill in a variety of contexts will result in substantial performance enhancement. A second training benefit from DMT is the opportunity gain experience in making decisions. Klein (2000) asserts that lack of experience is the primary reason for poor decision making. Without high levels of experience, decision makers often fail to recognize the implications of various situations and select inappropriate courses of action. Experience in DMT can augment aircraft experience by providing pilots with multiple opportunities to execute various tactics and to review the results of their actions.

In the next iteration of the DMT-FLUG training effort, we will be developing more comprehensive training and measurement capabilities that will permit us to identify which behaviors improve and how DMT helped in the improvement process. Our findings to date indicate that minimum capabilities for effective DMT include the following:

- DMT systems must be supported by programmable scenario generation tools that permit the incorporation of instructional principles and training strategies to foster skill development and retention.
- Mission replay and after-action reviewing capability are necessary capabilities for an instructionally viable training and rehearsal system.
- A construct-oriented individual, team and mission measurement system in place.

Simple practice or free-play are not efficient training strategies. Programmable scenario generation tools including computer-generated threats with the capability for autonomous action permit instructors to take advantage of findings from research on instructional principles to design training and rehearsal events that will meet specified objectives. In multi-ship air combat, training objectives for upgrading pilots include learning to recognize enemy aircraft formations and selecting an appropriate tactic, communicating the plan to the rest of the flight, executing the plan, and changing tactics as required. The programmable scenario generation tools in DMT-FLUG were used to create enemy formations and tactics that varied across a number of dimensions as summarized in Table 2. This range of scenarios combined with the opportunity for teams to fly several scenarios in an hour provide upgrading pilots with opportunities to gain experience with many more tactics and situations than would be possible in the aircraft.

Another key element in the success of DMT is the replay and debrief facility. In the AFRL testbed, each cockpit's radar, radar warning receiver, head-up display, and stores management system, are recorded and played back synchronized with a plan view display and all radio communications. The flight leader can pause, rewind, or zoom the display as required. Using the replay system, pilots can review the information that was available to them inside the cockpit together with the plan view display's depiction of the complete tactical situation. Execution errors, poor communication, and unplanned contingencies are quickly apparent. Debriefs were limited to 90 minutes for scheduling purposes which forced teams to focus on high level skills such as communication and execution without getting absorbed into analysis of individual, procedural skills.

Finally, it is important to note that the results presented in this report represent an evolution of our training paradigm from one of structured practice to one that is more focused on both objectives-driven instruction and construct oriented performance measurement. The lessons learned from this initial DMT-FLUG effort have provided considerable insight into the problems and needed capabilities associated with implementing a high fidelity, adaptive training and rehearsal system for Air Force pilots. The following summary describes future directions in research being undertaken at AFRL/HEA based on the results of DMT-FLUG.

Training needs assessment and content validation

In the next iteration of DMT-FLUG research, we will be conducting systematic assessment of training needs at other F-16 bases. The goal of the needs assessment is to elaborate the specific tasks and mission areas that are problematic for pilots in upgrade training. Additionally, the needs assessment will provide the necessary data to develop an instructionally principled curriculum. By focusing on key needs, we can design a syllabus that fosters the development and retention of skills needed for FLUG success. Moreover, the needs assessment will complement our current research activities in the definition of mission essential competencies, i.e., the knowledge, skills, attitudes, abilities and capabilities required for combat mission readiness. This effort will help us develop a more comprehensive, objectives-oriented syllabus for DMT-FLUG and identify the important performance parameters associated with mission effectiveness. It will also help us in the development of metrics to quantify training impact in terms of combat mission readiness and performance.

Development of Performance Criteria and Measurement Instruments

We are currently in the process of developing and testing evaluation instruments for individual and team effectiveness based on mission essential competencies. By adopting a competency-based approach to training development and evaluation, we are developing data collection and analysis methods for use across the entire spectrum of DMT activities (e.g., mission preparation, briefing, execution, and debriefing). Measurement techniques are being developed for analysis of verbal communications, pilots' mental models, team processes, and mission outcomes.

- Content analysis methods. Content-analysis instruments are being developed to evaluate verbal communications in order to better understand the quality of briefings, within-mission communication, and debriefings. In addition, measures of attitudes toward training,

motivation and perceived application and utility of the training have been developed for use in other training research and will be extended to FLUG.

- **Mental modeling assessments.** We are also conducting a series of studies on structured assessments of learning such as situational judgement assessments, mental modeling, Pathfinder, concept mapping, and multidimensional scaling. These are being applied to assess learning and understanding at both individual and team levels.
- **Process and outcome-oriented measurement.** Using mission essential competency definitions, it is possible to identify process-oriented behaviors that are associated with effective mission performance. We will then be able to develop process-oriented measures that will help us quantify the effects of DMT experience on individual and team knowledge acquisition, crew coordination/flight integrity (including leadership and assertiveness), situational awareness, communication, decision making/risk management, task management, and mission planning/debrief. As a part of these activities, we will develop, test, and validate protocols to capture data related to the identified processes. The key process behaviors and metrics will be used to further refine training objectives and to identify opportunities to improve training content and training policy.

Finally, we are evaluating the reliability and validity of mission outcome measures such as "Turkey Shoot" and "Top Gun" scoring. Based on this evaluation, we will be refining, automating, and applying measures for simulator and flying performance. It is critical that any developed measurement system provide reliable and valid data to demonstrate that training has had an impact on actual aircrew competencies, attitudes toward training, motivation to train, expectations regarding training and transfer, knowledge mastery and subsequent job performance. Furthermore, the data and instrumentation will serve both a formative assessment function by providing feedback on problem areas in the training, and a summative function by permitting cost and mission impact assessments.

Summary

DMT research has demonstrated both the utility and effectiveness of DMT to complement aircraft training. DMT supports operational training needs training by providing opportunities for pilots to plan, brief, fly, and debrief many more air-to-air missions than currently possible in aircraft. In addition, DMT provides instructors the capability to choose scenarios that exercise selected skills. New research will focus on developing a comprehensive training syllabus that will incorporate needs analysis, specification of essential competencies, scenario development and selection based on principles of instruction, and performance measurement systems that will assess both mission outcome and team processes.

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Development of Models of Alternative Space Training Structures

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The U.S. Air Force Space Command encompasses over 30 career fields of varying skill/knowledge and training requirements, which provide support directly or indirectly to the mission of Space Command. In today's environment of tight budgets and rapidly changing technologies, the career field structure and training requirements within the auspices of Space Command are encountering new and challenging requirements. Space Command is directly for the training and career field management of two AFSs: space systems operations (1C6x1 - enlisted) and space and missile operations (13Sx - officer). These new requirements for the two career fields under Space Command, as well as the numerous enlisted career fields which support Space Command, must be achieved with cost effective and efficient education and training programs. Modification and/or enhancement to the career field education and training program must provide the necessary skills for accomplishing the job and tasks of the present and must be adaptable to the needs of the future. Technologies or models, which allow career field planners and managers to carefully evaluate the costs, monetary and non-monetary, of changes in training needs, are essential to management decision-making. Such technologies as the Training Impact Decision Support System (TIDES), the Training Effectiveness and Efficiency Model (TEEM), and Job Structuring Technology (JST) provide career field managers with tools to evaluate the affects of career field structure and training changes from the perspective of costs, mission readiness and productivity. These tools form the basis for supporting and evaluating career field policy modifications and changes, as well as providing a catapult into future evaluation of training re-engineering such as CBT or distance learning.

Training Impact Decision Support System (TIDES)

The TIDES system allows manpower and functional managers to examine trade-offs between different training scenarios for enlisted Air Force specialties (AFSs). TIDES technology helps Air Force training managers balance an occupation's training needs versus resources and requirements. This balance of needs and requirements allows training managers to optimize training management throughout the entire career of an individual or group of individuals (this includes all training, formal and informal, as well as all jobs an individual could perform throughout their career with the Air Force). Such specialized groups of individuals have different training needs, and substantial economics are possible through tailored job training. TIDES technology provides analysts and decision-makers with a tool to systematically analyze and integrate information about jobs, tasks, career assignments, personnel flows, and technical training programs within an Air Force occupation (or groups of related occupations).

By dynamically modeling an occupation's career flow patterns, the TIDES technology provides a "what if" capability to assess the long-term impact of current and future constraints stemming from changing training, personnel and fiscal policies and resources. TIDES analyses also aid

decision-makers in determining what tasks associated with an occupation to train, when to provide that training (at what career points), and the method best suited for that type of training.

TIDES "What If" Modeling

In general, TIDES "what if" modeling involves creating alternative job and training patterns reflecting manpower, personnel, and training policy options of interest. This can be done by a TIDES analyst or modeler, or by an Air Force decision-maker, such as the functional manager for the career field at Headquarters Air Force or Major Command, or in a group session such as a U&T (Utilization and Training) Workshop. Once an alternative is specified, the model is run on the alternative job and training patterns, and model results are compared to those for the baseline model (the current job and training pattern).

While such relationships may have been intuitively obvious to some managers in the past, it is only now that such relationships can be quantified and reported to support and justify necessary training investment decisions. The types of information and data displays provided in a decision support system such as the TIDES can be crucial for helping managers and other decision makers improve their understanding of the potential impact or consequences of their decisions. Further, such a system will also help them document the rationale for such decisions, and defend such decisions to higher levels of command within the Department of Defense and to Congress.

TIDES Success

During the development of TIDES, tests were run on numerous diverse Air Force occupations: fairly homogeneous career fields such as the B-1 Avionics Test Station with two jobs plus supervisors, very structured specialties such as Security and Law Enforcement with 85 job variations, and complex electronics career fields such as the Radar and Inertial Navigation Systems technicians with many distinct jobs by equipment system each with its own advanced skills training course. Occupations with high volume of trainees and complex tasks were also analyzed.

One of the occupations studied dealt with sophisticated computers and switching equipment systems maintenance. The equipment was so complex that the training and personnel were specialized by the type of equipment they maintained. Problems were beginning to show up at a senior level; technicians were so specialized that they knew little about the entire occupation. Therefore, when decisions were being made, certain specialty areas may have been under-emphasized due to the lack of the decision-makers' experience with some equipment.

TIDES was used to examine various ways to collapse the seven separate tracks into a smaller set of subspecialties; the formal consensus among representatives of the various constituencies (at a U&T Workshop) was for a common (general) track plus three specialized tracks. This consolidation reduced the overhead needed to manage the occupation and will increase the experience base for future senior technicians. Most importantly, when combined with other Air Force personnel policy changes, including increasing average assignment times from 32 to 48 months, there was a potential reduction or avoidance of \$1.7 million in annual training costs, even though each new individual would receive more complete training than in the past.

A study was conducted within the Air Force security police career field investigating the possibility of out-sourcing/privatization parts of their initial skills training. A proposal was made to accept applicants with associate degrees or a certification program in place of conducting full scale ABR, 3 level training. The potential cost savings for bypassing the course was determined for management review and consideration.

Another study was performed for OASD to determine the cost savings and break-even point for initial skills and 7-level training for three diverse AFSs (aerospace propulsion, medical technicians, and pavements). The study indicated that the cost savings from technology insertion (primarily CBT) varied significantly due to several key factors such as course flow, length of course, technical rigor of subject matter, student to teacher ratio, etc. The results indicated that across the board technology insertion was not economically viable requiring a course by course consideration to determine the economic viability of re-engineering.

TIDES Current Efforts

The TIDES technology runs in a PC-based, MS Windows environment. Once an initial TIDES data base for a specialty has been developed, TIDES users are able to sit at their personal computers, formulate and run various scenarios weighing the alternatives, and forecast the impacts of decisions before they become policy. The advanced work includes a template (software [MS Word])for Career Field Education & Training Plans (CFETPs) to service a HQ USAF/DPPE need. The payoff to the USAF is a systematic method to enable career field, functional, and training managers to maximize efficiency and training effectiveness while minimizing training costs, yet still provide the means to produce the highest quality mission-ready trained forces.

Training Effectiveness and Efficiency Model (TEEM)

TEEM was developed for the Human Resources Directorate of the Armstrong Laboratory as a methodology that facilitates the use of training evaluation data. TEEM links information from the field to information from the course in an automated process and displays that information in a graphical manner, which then allows course designers, developers, and decision-makers to view and identify data trends. Specifically, it is a computerized, task-based training evaluation methodology that integrates Occupational Survey, course, efficiency, effectiveness, and transfer data at the same level of specificity to facilitate course revisions and improve training quality. TEEM allows users to manipulate, display, and print all results produced by this methodology.

Training efficiency examines whether the appropriate amount of time is devoted to training tasks, or whether tasks are potentially over- or under- trained. Task-level occupational survey information, such as Task Learning Difficulty, which is based on the notion of time to learn, is compared to the actual amount of time devoted to training each task in a course. The results are then graphically depicted as one of three outcomes. A training match is depicted if the estimated time to learn, for example, is relatively the same as the actual time devoted to training that task, indicating that the relative amount of time devoted to training that task seems appropriate. A potentially over-trained task is depicted if relatively more time is spent training a task, compared to the corresponding time to learn estimate, indicating that training time might be reduced for

those tasks. A potentially under-trained task is depicted if the time to learn estimate is relatively greater than the corresponding actual training time, indicating that more training time needs to be allocated to those tasks. Thus, each task taught in training is graphically displayed as one of these three outcomes.

The results of the three matching outcomes are then integrated with training effectiveness information. Training effectiveness examines whether course graduates perform tasks above or below a specified standard later on the job. A 2 X 3 matrix is then utilized to display the effectiveness and efficiency integration. Two columns represent the training effectiveness for each trained task as above or below the training standard. Three rows represent the three potential outcomes from the efficiency results: a match, a potentially over-trained task, and a potentially under-trained task. Thus, a task may fall into any of the six boxes of this 2 X 3 matrix. For example, a task performed below standard may also be under-trained, indicating that more training time might be allocated to that task to improve its effectiveness.

Finally, efficiency and effectiveness results are integrated with training transfer data. Training transfer examines whether or not learning transfers from the course to the job. Efficiency is measured in terms of the average number of times each task is performed on the job. Effectiveness is measured in terms of graduate abilities to apply what was taught. This information is integrated into the 2 X 3 matrix and is displayed with the tasks that fall in each box to allow course designers to see, in one place, all of the data that are related to each task.

Examined separately, the results of training efficiency, training effectiveness and training transfer data provide useful information for understanding and changing different aspects of a training system. Results of the matching technique suggest that the course efficiency can be improved by reducing training time for over-trained tasks and increasing training time for under-trained tasks. Training effectiveness data suggest that for tasks performed below the performance standard, course revisions may be necessary while tasks performed above standard are less likely to require course changes. Training transfer data indicate that more task experience might be required early on-the job to facilitate job performance where the opportunity to perform the trained tasks is low. However, these data are more useful when considered in combination. For example, the results illustrate how a training program can be re-designed to be more efficient by reducing training time for over-trained tasks that were performed above standard, while increasing training time for under-trained tasks that were performed below standard. Furthermore, the training transfer information is useful in determining whether the training program itself should be modified, or the transfer environment changed. For example, if a task is under-trained, the amount of practice on the job is sufficient, but it is performed below standard, the training program might be modified by increasing the training time for that task. Alternatively, if an over-trained task is performed below standard on the job, yet the amount of practice for that task is low, modifying the training program is probably not a reasonable action. A better solution might be to ensure training graduates receive more practice for that task on the job, or consider eliminating it from training, and allocate that time to other tasks in the program. Of course, other options should always be considered, such as developing improved instructional approaches.

Job Structuring Technology (JST)

The Job Structuring Technology (JST) currently being developed for AL/HRMJ examines possible AFS mergers or restructuring based on task modules. Such modules are semantically linked to knowledge domain lexicons developed from Office of Personnel Management (OPM) civilian series descriptions. This technology has the goal of targeting specific occupational areas and evaluating potential scenarios to optimize force structuring based on Mission-Essential Modules (MEMs) of tasks (Driskill, Weissmuller, Moon & Black, 1995). Support tools developed for use in this project include a Historical AFSC Information Locator System (HAILS) to track specialty changes across time, lists of current occupational analysis and research studies and requirements, and eventually will include CFETP and other required documents. The prototype HAILS has already been delivered to AL/HRMJ as well as to the Air Force Occupational Measurement Squadron for operational use as an AFS reference system.

This project developed the prototype of the Structuring Technology (JST), a microcomputer-based system that simulates the processes and activities of force planners; mission designers and planners; manpower, classification, assignment-placement, and promotion personnel; and training planners when changes in officer and enlisted specialty classification structures appear to be warranted. Underlying the system is the premise that the primary requisite of classification structure should be to support Air Force mission requirements. In the broadest sense, classification structure either drives or heavily influences force planning, such personnel functions as assignment and career progression, manpower planning, and training design and delivery. The JST is a decision aid to support design or restructuring of classification structures that provide the most efficient and effective support of mission requirements through the evaluation of impacts of the structure on the force management, manpower, personnel, and training functional requirements.

The system employs an array of data, available from a variety of Air Force databases, and incorporates software to apply these data to prototype as well as evaluate and trade-off among classification structure options from which the various personnel must make operational decisions. Design features include such capabilities as assessing changes among a few (two or three) Air Force Specialties, large-scale reorganization (comparable to the reorganization in the immediate past), and creation of new specialties.

The JST software includes state-of-the art semantic-assisted analytic techniques for satisfying a basic requirement of any classification methodology. Specifically, aside from the requirement to support mission requirements, a fundamental reason for classifying a large variety of work requirements, especially diverse work requirements, into some structure is to maximize productivity. This purpose is most efficiently satisfied when workers not only are trained most cost effectively, but once trained can migrate from job to job within a work category with a minimum of on-the-job training and loss of productivity. Implicit in this purpose is the need to "classify" jobs according to the commonality or homogeneity of knowledge, skill, and ability requirements, not only at general levels of commonality but at the most specific level possible. The semantic-assisted software in the JST is designed to permit definition of homogeneity at different levels, including the specific level from which optional scenarios of classification structure can be generated and evaluated for impacts on the other functions as well as operational utility.

The JST analyzes the commonality of work requirements within each of the job descriptions. The system provides methods for reading each of the requirements, assigning weights to the objects worked on and the actions taken, and using these weights to assess the homogeneity and/or diversity of work through comparison of how similar work is structured by well-recognized, accepted, and time tested classification methodologies. The system also can compare among different job descriptions. It is during this process that the JST semantic-assisted analytic software not only reads job requirements, but also interprets among them in terms of those that are most homogeneous.

Further, JST processes provide planners (including the classifier as well as other functional managers) the opportunity for the generation of alternative ways to distribute the body of work required by a mission manager. Each of the options then can be assessed with regard to its impact on the other essential planning functions (e. g., manning, training), compared so that potential tradeoffs are identified, and an operational decision about classification of jobs can be made.

The JST is appropriate for considering such decision possibilities as mergers of two or more specialties, separation of one specialty into multiple specialties, or distribution of the work of a specialty into other existing or newly created specialties. In each case, specialty descriptions can be read, weights computed (based on within-specialty importance), commonality of work requirements assessed, optional configurations generated, impacts of the options evaluated, tradeoffs identified, and revised or new structure decided upon.

Integrated Training Technologies (INTTECH)

The military and civilian training communities have a continuing need for innovative analysis and modeling tools, which improve the ability to capture and more accurately access the responses of individuals and systems. At the core of many simulations or analyses are models, which embody changes in such responses to current or expected training requirements and conditions. The approach to building these models or representations is similar whether the problem is the identification of training emphasis, the maintenance of a turbine engine from its expected condition, the reaction of military personnel to changes in career training requirements, or the maintenance and control of complex computer systems supporting weapons systems. Recent advances in modeling and simulation techniques, occupational data collection, and model selection methods have suggested more powerful approaches for capturing richer and more realistic estimates of impacts for changes in training programs and personnel policies. INTTECH addresses the need for a common tool (platform) to provide sophisticated analysis, representation, and modeling of training and training policy and recognizes the requirement that such a tool be capable of inter-operation with existing and planned training policy tools.

Through many years of research, Armstrong Laboratory and its collaborators developed and evaluated methodologies and techniques to capture the effects of changes in training programs, requirements, and policies. Most of the prototype technologies developed have been to support and improve of Air Force specialty (AFS) decision making on training and utilization policies. Ultimate responsibility for decisions on AFS training rests with the Air Staff Career Field Manager (CFM) but such decisions are usually supported by the advice and concurrence of MAJCOM functional managers, technical training managers, occupational analysts, and military

personnel classification personnel through Utilization and Training Workshops (U&TWs). This integrated decision making process is now mandated under Air Force Manual 36-2245, Managing Career Field Education and Training, 30 June 1995.

TIDES, TEEM and JST described above are based on various levels of task information, some at the task module level and some with linkages to other kinds of information (required knowledges, equipment used, skills required, etc.). To be useful to decision makers, such data must be easily transportable among the various technologies, which requires development of software capable of handling multiple levels of task data (tasks, task modules, metamodules, etc.). Additional research and development is needed, during the development of the integrating software platform, to determine appropriate statistics needed when moving from task-specific to more generic levels, or across occupational areas.

Implementation of emerging training technologies into a common facility involves exploratory research into the methodology for communicating among the technologies to be resident on the system, prototyping of the facilities, and final development and implementation of the facilities into a new Integrated Training Technologies (INTTECH) platform. From a research perspective, there are a number of challenges that must be addressed to link the training R&D technologies together in a common platform. One of the greatest challenges is related to determining the appropriate level or unit of analysis that serves as the basis for linking the initial technologies together. TEEM, TIDES and JST are technologies that examine career field training at distinctly different levels of analysis. The TEEM is designed to provide information for evaluating formal training courses within a career field. TEEM focuses on the more micro-level aspects of the career field training. TIDES was designed to examine and model job and training requirements for an entire career field. That is, at a more macro-level. Output from TIDES could be provided to TEEM as course requirement specifications. Output from TEEM can be incorporated in the TIDES for formal course design and revision. Additionally, TEEM output might provide critical information for validating training time and training allocation models in TIDES.

INTTECH provides a basis for identifying and testing alternative linkage approaches, assessing the impact of integration on the quality of analysis results from the actual technologies, and developing and demonstrating a common technology platform. INTTECH will systematically link and integrate the three technologies such that information and data could be dynamically shared among manpower, personnel, job, and training technologies together in a common platform similar to that which is available in a software suite such as Microsoft Office. INTTECH will provide the basis for supporting and evaluating career field policy modifications and changes, as well as providing a catapult into future evaluation of training re-engineering such as CBT or distance learning.

unwanted and unused. A primary goal of DMT research at AFRL/HEA is to provide commanders and instructors at MTCs with effective and validated training tools and materials including training protocols to meet specific needs, sample scenarios, and performance assessment instruments. The laboratory's objective is to assist Air Force warfighters use DMT systems to effectively and efficiently augment flying training.

Background

Research on training effectiveness of multi-ship simulation systems has been on-going at AFRL/HEA for almost ten years. In addition to research on networked simulation technologies, activities have focused on application of DMT for continuation training of fighter pilots and air weapons controllers. Hoog (1999) described how DMT systems are being designed to enhance skills that warfighters will employ both as individuals and as members of a team. Effective application of multi-player simulation for enhancing individual and team skills has been demonstrated for F-15 pilots (Houck, Thomas, & Bell, 1991), F-16 pilots (Berger & Crane, 1993), Tornado pilots and navigators (Huddleston, Harris, & Tinsworth, 1999), pilots, forward air controllers, and ground forces executing close air support (Bell, et al., 1996), and Air Force Special Operations teams (Nullmeyer & Spiker, in press). F-16 pilots who have flown in a distributed environment have rated DMT as particularly effective for training four-ship air-to-air employment against multiple enemy aircraft (Crane, Schiflett, & Oser, 2000). F-16 pilots have identified individual skills including radar mechanization (i. e., using the various modes and capabilities of the air-to-air radar to detect, track, and target multiple aircraft), communication, and building situation awareness as being enhanced by DMT. Team skills enhanced by DMT include maintaining mutual support, tactical execution, and flight leadership.

One of the most critical aspects of developing high performance flying missions is related to the identification of mission essential competencies that can be used to define combat readiness. The Air Force has attempted to specify readiness and mission performance requirements at a number of levels of abstraction. These levels of abstraction include very specific task level behaviors that must be performed to operate fighter aircraft. They also include very broad statements of the Air Force Mission Essential Tasks, which are global statements of the overall missions and goals of the Air Force and its component organizations. In most cases these more specific task level behaviors are the focus of Undergraduate Pilot Training and Initial Qualifications Training (IQT).

From the time an Air Force pilot completed IQT until they are certified as "Combat Mission Ready" they are basically required to completed a variety of formal and information training and operational requirements as a part of the Ready Aircrew Program (RAP). However, the specificity of

Crane (1999) reported that F-16 instructor pilots participating in DMT research would frequently fly as flight leader for the morning mission but would then assign a less experienced pilot to serve as flight lead during the afternoon. The instructors explained that these pilots were participating in Flight Lead Upgrade (FLUG) training at their squadrons and that DMT was a valuable complement to aircraft training. As applied to FLUG training, results to date demonstrate that experience in DMT enhances leadership skills for multi-ship, multi-bandit air combat. This is most likely a function of both DMT system capabilities and constraints on

pilots' ability to train in the aircraft that limit opportunities for gaining experience over a wide range of tactical situations. Observations of pilots during DMT-FLUG exercises demonstrated that increases in mission performance resulted from both enhanced skills and from opportunities to review missions and to assess the results of individual actions.

One of the objectives of DMT-FLUG research was to identify the ways in which DMT experience could increase pilot readiness for FLUG missions. These examples illustrate two training benefits of DMT. The first is providing increased opportunities to train individual skills that must take place in a multi-player context. Radar sorting and targeting requires multiple friendly and enemy aircraft; opportunities to practice this skill in the air are highly limited. DMT provides many opportunities to practice this skill in a naturalistic context and within a short period of time. This observation is in agreement with Bell (1999) and Schneider (1989) who propose that multiple opportunities to practice a skill in a variety of contexts will result in substantial performance enhancement. A second training benefit from DMT is the opportunity gain experience in making decisions. Klein (2000) asserts that lack of experience is the primary reason for poor decision making. Without high levels of experience, decision makers often fail to recognize the implications of various situations and select inappropriate courses of action. Experience in DMT can augment aircraft experience by providing pilots with multiple opportunities to execute various tactics and to review the results of their actions.

In the next iteration of the DMT-FLUG training effort, we will be developing more comprehensive training and measurement capabilities that will permit us to identify which behaviors improve and how DMT helped in the improvement process. Our findings to date indicate that minimum capabilities for effective DMT include the following:

- DMT systems must be supported by programmable scenario generation tools that permit the incorporation of instructional principles and training strategies to foster skill development and retention.
- Mission replay and after-action reviewing capability are necessary capabilities for an instructionally viable training and rehearsal system.
- A construct-oriented individual, team and mission measurement system in place.

Simple practice or free-play are not efficient training strategies. Programmable scenario generation tools including computer-generated threats with the capability for autonomous action permit instructors to take advantage of findings from research on instructional principles to design training and rehearsal events that will meet specified objectives. In multi-ship air combat, training objectives for upgrading pilots include learning to recognize enemy aircraft formations and selecting an appropriate tactic, communicating the plan to the rest of the flight, executing the plan, and changing tactics as required. The programmable scenario generation tools in DMT-FLUG were used to create enemy formations and tactics that varied across a number of dimensions as summarized in Table 2. This range of scenarios combined with the opportunity for teams to fly several scenarios in an hour provide upgrading pilots with opportunities to gain experience with many more tactics and situations than would be possible in the aircraft.

Another key element in the success of DMT is the replay and debrief facility. In the AFRL testbed, each cockpit's radar, radar warning receiver, head-up display, and stores management system, are recorded and played back synchronized with a plan view display and all radio communications. The flight leader can pause, rewind, or zoom the display as required. Using the replay system, pilots can review the information that was available to them inside the cockpit together with the plan view display's depiction of the complete tactical situation. Execution errors, poor communication, and unplanned contingencies are quickly apparent. Debriefs were limited to 90 minutes for scheduling purposes which forced teams to focus on high level skills such as communication and execution without getting absorbed into analysis of individual, procedural skills.

Finally, it is important to note that the results presented in this report represent an evolution of our training paradigm from one of structured practice to one that is more focused on both objectives-driven instruction and construct oriented performance measurement. The lessons learned from this initial DMT-FLUG effort have provided considerable insight into the problems and needed capabilities associated with implementing a high fidelity, adaptive training and rehearsal system for Air Force pilots. The following summary describes future directions in research being undertaken at AFRL/HEA based on the results of DMT-FLUG.

Training needs assessment and content validation

In the next iteration of DMT-FLUG research, we will be conducting systematic assessment of training needs at other F-16 bases. The goal of the needs assessment is to elaborate the specific tasks and mission areas that are problematic for pilots in upgrade training. Additionally, the needs assessment will provide the necessary data to develop an instructionally principled curriculum. By focusing on key needs, we can design a syllabus that fosters the development and retention of skills needed for FLUG success. Moreover, the needs assessment will complement our current research activities in the definition of mission essential competencies, i.e., the knowledge, skills, attitudes, abilities and capabilities required for combat mission readiness. This effort will help us develop a more comprehensive, objectives-oriented syllabus for DMT-FLUG and identify the important performance parameters associated with mission effectiveness. It will also help us in the development of metrics to quantify training impact in terms of combat mission readiness and performance.

Development of Performance Criteria and Measurement Instruments

We are currently in the process of developing and testing evaluation instruments for individual and team effectiveness based on mission essential competencies. By adopting a competency-based approach to training development and evaluation, we are developing data collection and analysis methods for use across the entire spectrum of DMT activities (e.g., mission preparation, briefing, execution, and debriefing). Measurement techniques are being developed for analysis of verbal communications, pilots' mental models, team processes, and mission outcomes.

- Content analysis methods. Content-analysis instruments are being developed to evaluate verbal communications in order to better understand the quality of briefings, within-mission communication, and debriefings. In addition, measures of attitudes toward training,

motivation and perceived application and utility of the training have been developed for use in other training research and will be extended to FLUG.

- **Mental modeling assessments.** We are also conducting a series of studies on structured assessments of learning such as situational judgement assessments, mental modeling, Pathfinder, concept mapping, and multidimensional scaling. These are being applied to assess learning and understanding at both individual and team levels.
- **Process and outcome-oriented measurement.** Using mission essential competency definitions, it is possible to identify process-oriented behaviors that are associated with effective mission performance. We will then be able to develop process-oriented measures that will help us quantify the effects of DMT experience on individual and team knowledge acquisition, crew coordination/flight integrity (including leadership and assertiveness), situational awareness, communication, decision making/risk management, task management, and mission planning/debrief. As a part of these activities, we will develop, test, and validate protocols to capture data related to the identified processes. The key process behaviors and metrics will be used to further refine training objectives and to identify opportunities to improve training content and training policy.

Finally, we are evaluating the reliability and validity of mission outcome measures such as "Turkey Shoot" and "Top Gun" scoring. Based on this evaluation, we will be refining, automating, and applying measures for simulator and flying performance. It is critical that any developed measurement system provide reliable and valid data to demonstrate that training has had an impact on actual aircrew competencies, attitudes toward training, motivation to train, expectations regarding training and transfer, knowledge mastery and subsequent job performance. Furthermore, the data and instrumentation will serve both a formative assessment function by providing feedback on problem areas in the training, and a summative function by permitting cost and mission impact assessments.

Summary

DMT research has demonstrated both the utility and effectiveness of DMT to complement aircraft training. DMT supports operational training needs training by providing opportunities for pilots to plan, brief, fly, and debrief many more air-to-air missions than currently possible in aircraft. In addition, DMT provides instructors the capability to choose scenarios that exercise selected skills. New research will focus on developing a comprehensive training syllabus that will incorporate needs analysis, specification of essential competencies, scenario development and selection based on principles of instruction, and performance measurement systems that will assess both mission outcome and team processes.

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Adaptive, Internet Survey Techniques for Determining Critical Pilot Training Tasks and Requirements

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Background

Aircraft and system acquisitions are expensive investments, both in terms of initial acquisition and lifecycle costs. A primary focus of most new system acquisition programs is "affordability." Specifically, this entails reducing the costs of development, production, and ownership through definition, demonstration, and transition of innovative concepts and advanced technologies that will significantly reduce system costs while meeting the operational requirements of the customers (i.e., the services). One strategy being used to reduce costs is to maximize commonality among air vehicle variants and systems, while providing unique features that maximize capabilities for diverse missions. Another strategy for aircraft acquisition includes eliminating the need for a two-seat aircraft version for training. This would provide cost savings in terms of design, production, maintenance, and manpower. However, in order to ensure that there would be no reduction in training effectiveness or safety, a methodology needed to be developed to examine the purpose of current two-seat training and to explore training and aircraft design options that might help mitigate the need for this expensive training variant. The purpose of this paper is to describe a methodology for collecting field data to support the acquisition and design process.

Objectives

The research team was tasked to conduct a study analyzing elements of new aircraft pilot training that would potentially be impacted by a decision not to build a two-seat training variant. The goal of this study was to assist acquisition decision makers in the Engineering, Manufacturing, and Development phase by identifying the critical pilot training issues of safety and effectiveness for tasks currently trained in two-seat aircraft variants. This study's findings and recommendations will help the program offices ensure that the critical issues are adequately addressed and resolved by the weapon system contractors through aircraft design or training system innovation.

This study gathered key information about appropriate training strategies from instructor pilots (IPs) of existing strike aircraft of several services. This information will be used to generate recommendations to ensure that new aircraft and training system designs will mitigate any risks. Several training strategies and aircraft configurations are plausible and

combinations of strategies may provide the best options for the various aviation communities. To enhance the validity of decisions made based on information derived from this study, this project used subject matter expert (SME) input from current strike fighter aircraft IPs from various services and countries participating in new aircraft acquisition programs. There are two primary objectives of this survey:

Objective 1 - Determine why certain tasks for current aircraft are trained in 2-seat models.

Objective 2 - Determine what training methods could be used to safely and effectively train tasks currently trained in a 2-seat aircraft if there are no 2-seat aircraft available.

Methods

Workshop

The project team for this study consisted of two occupational survey analysts, an industrial/organizational psychology professor from Texas A&M, and two research psychologists who specialize in U.S. Air Force and Navy aviation training. The project team conducted a two-day workshop with a diverse group of IP subject matter experts to construct the appropriate survey items and response options to meet the defined objectives. The IPs represented legacy strike fighter aircraft communities. Specifically, the instructor pilots consisted of:

a UK Royal Navy F/A2 former IP) who works at a new aircraft program office as the lead for UK operational requirements;

two USAF F-16 pilots who were also exchange pilots with the RAF flying GR7s, one of whom was an IP for F-16 initial qualification training and the other was an IP for undergraduate pilot training;

one USN F/A-18 IP; and

one USMC AV-8B IP who accomplished the task and syllabus matching off-line from the workshop.

The project team began the workshop by giving an overview of a new aircraft acquisition program and its various roles/missions, performance characteristics, and planned system capabilities. The project team then defined for the SMEs the objectives of the study and suggested types of survey items that might be appropriate for answering those objectives. The IPs reviewed each of their respective services' aircraft training syllabi, course training standards, and master training task lists to identify the tasks and skills currently trained in two-seat versions of their aircraft. The IPs then generated a single list, using common

terminology, of all the major tasks that are trained in the various services' two-seat aircraft.

Having a common list will enable an analysis of the data across the different services for tasks that are common to several or all of the services. The master list contained 44 two-seat tasks, of which, the USAF F-16 train 33, the USN and USMC F/A-18 train 26, the USMC AV-8B train 28, and the UK RN and RAF train 43. In addition, each IP identified the appropriate legacy syllabus event in which those tasks are trained, and what type of instructor pilot is responsible for teaching that task.

To meet the first objective of the study, determining why certain tasks are currently trained in two-seat models, the project team and SME's constructed a set of survey items that asked respondents to assess the importance of each of the four roles for an IP who is in the back-seat while training each of the identified two-seat tasks. The four major functions of the IP were determined to be (a) Ensure Safety of Flight, (b) Demonstrate Execution of Task, (c) Provide Immediate Feedback/Instruction, and (d) Assess Performance. Since an IP often performs more than one of these functions concurrently from the back seat, we asked the survey respondents to rate the importance of each function for each specified task on a scale of 0 to 4 (0 being "Not at all important" and 4 being "Absolutely Important").

Since new aircraft might only have single-seat versions of the aircraft, even for training, this study collected data from survey participants on potential aircraft capabilities or training system technologies that might be required to train these types of tasks with minimal levels of risk and high levels of training effectiveness. With the combined knowledge of the project team and SMEs, a list was generated with supporting definitions of aircraft capabilities that might enable, or obviate the need for, an IP to perform the four functions identified above in the absence of a two-seat training aircraft. These aircraft capabilities included such items as a chase aircraft, ground-collision avoidance system, and advanced handling characteristics (See Table 1).

In addition to the list of aircraft capabilities, the project team and SMEs developed a list of simulation technologies with supporting definitions, for both existing and emerging concepts, that could be used to facilitate or enhance training, or for evaluation of competency before a student must perform those tasks in the aircraft (see Table 1).

Table 1. List of aircraft and simulator capability response options used on the survey

Aircraft Capabilities	Simulator Capabilities
No enhanced aircraft capabilities or instructor in another aircraft required	Not Required For Training
Instructor in Another Aircraft	Basic Simulator
In-Flight Data Link	High Physical and Functional Fidelity Cockpit
Ground Data Link	Photo-Realistic Visual Database
Ground Collision Avoidance System (GCAS)	360-Degree FOV Visual Displays with 20/20 Resolution
Advanced Handling Characteristics	Realistic Weather Effects
Mission Recorder	Networked Simulators
Automation	Accurate Sensor Models
Other	Motion-Based
	Force Cueing
	Other

Survey Construction and Layout

Because of the requirement to survey populations at disparate sites, as well the uniqueness of the survey based on the different tasks from the master list that are actually relevant to the different services, the project team used an adaptive, internet-based survey construction and delivery tool called GenSurv (Bennett, 1999; Mitchell & Weissmuller 1999). This survey tool allowed the survey to branch based on the service, aircraft type, and instructor pilot qualifications.

The survey began by explaining the purpose of the study and providing some background information on the new aircraft, to include its expected missions and capabilities. The survey then had a section to gather demographic information from each respondent which was branched and tailored to each service. The next section was constructed to collect data to address the first objective, assessing the importance of the IP functions for each task currently trained in two-seat training aircraft. This section began by defining the functions and then asked respondents to assess the importance for each of the tasks relevant to their legacy aircraft type and their instructor qualifications.

The next section addressed the second objective of determining aircraft and simulation capabilities that would be required to safely and effectively train those same tasks with only a single-seat aircraft available. It began by having the respondent read through the response options and their detailed definitions. Participants were then asked to identify any and all of the aircraft and simulation capabilities they thought would be required for each relevant task (see Table 1).

The final section included a general comment section for respondents to provide any additional inputs on these training issues they felt might be useful and gave an option for the respondents to provide personal contact information.

In addition to being able to create an adaptive survey based on the branching described above, there are other features of GenSurv that were extremely useful for constructing the survey and using the instrument to collect the data. GenSurv allowed the survey developers to require an appropriate response before a participant could proceed to the next item. Another key feature used throughout the survey, was allowing for or requiring, open-ended responses or comments which helped to collect a richer set of information for the study. Because the survey is Internet-based, the instrument developers inserted links to a new aircraft program office web site for respondents seeking more information. There were also pictures from simulation visual databases to illustrate some of the advanced simulation capabilities that new aircraft training systems could employ.

Alpha and Beta Tests

After the survey was developed with GenSurv and hosted on a server, an alpha test of the survey was conducted with the project team and SMEs who helped develop the survey. Based on feedback from project team members and SMEs, changes were made to clarify the objectives and to enhance the presentation and usability of the survey. A limited beta test was also conducted with IPs who were not part of the survey development to ensure usability and clarity to pilots of the targeted population, and to ensure complete and accurate coverage of two-seat tasks for each aircraft community. The feedback from the beta test showed that the survey was ready for implementation across the targeted population.

Field Data collection

The project team's goal for the survey was to generate a sample of at least thirty current or recent instructor pilots from each legacy aircraft community, resulting in a final sample of 120 participants. Data collection began on September 7 and the web site was closed on October 6, due to program schedule constraints. At the conclusion of the data collection, 48 completed survey responses had been received from the following aircraft communities: 8 from United Kingdom GR7 and F/A2 IPs, 10 from AV-8B IPs, 18 from F-16 IPs, and 12 from F/A-18 IPs.

Conclusion

Analysis of the data has just begun. Currently, the background data and raw database are being evaluated for completeness. Results are expected to highlight areas that may require risk mitigation, either through innovative aircraft design or implementation of innovative training technologies and strategies. Results may indicate a need to extend the data collection effort to increase the sample size or highlight areas that require a more detailed study and analysis to fully understand the critical safety and training effectiveness

issues. The data need to be summarized in such a way as to represent the professional opinions of this sample of pilots as to how training should be conducted with new systems. This will assist new aircraft acquisition decision makers in guiding the development of the aircraft and its pilot training systems to mitigate risks and ensure effective training.

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